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Environmental Radioactivity in Greenland in 1970

by

A. Aarkrog and J. Lippert

The Danish Atomic Energy Commission
Research Establishment Risø
Health Physics Department

Abstract

Measurements of fall-out radioactivity in Greenland in 1970 are reported. Sr-90 (and Cs-137 in most instances) was determined in samples of precipitation, sea water, vegetation, animals, and drinking water. Estimates of the mean contents of Sr-90 and Cs-137 in the human diet in Greenland in 1970 are given.

CONTENTS

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Our thanks are furthermore due to the district physicians, the telestations, GTO, and all other persons and institutions in Greenland and Denmark who have contributed by collecting samples.

ABBREVIATIONS AND UNITS

FP	fission products
pCi	picocurie, 10^{-12} Ci, $\mu\mu$Ci
nCi	nanocurie, 10^{-9} Ci, mμCi
mCi	millicurie, 10^{-3} Ci
S. U.	pCi Sr-90/g Ca
M. U.	pCi Cs-137/g K
nSr	natural (stable) Sr
S. D.	standard deviation, $\sqrt{\frac{\Sigma(x-x_i)^2}{(n-1)}}$
S. E.	standard error, $\sqrt{\frac{\Sigma(x-x_i)^2}{n(n-1)}}$
S. S. D.	sum of squares of deviation, $\Sigma(x-x_i)^2$
f	degrees of freedom
s^2	the variance
v^2	the ratio between the variance in question and the residual variance
P	the probability fractile of the distribution in question
η	coefficient of variation, relative S. D.

1. INTRODUCTION

1.1.

In 1970 the sampling programme from the previous years was used with only a few modifications.

1.2.

As hitherto, the samples were collected through the local district physicians and the heads of the telestations. However, it is still impossible to obtain all samples scheduled in the programme.

1.3.

The estimated mean diet in Greenland was unchanged as compared with 1962, i.e., it was in accordance with the estimate given by Professor E. Hoff-Jørgensen, Ph.D., nutritional consultant to the Danish Atomic Energy Commission.

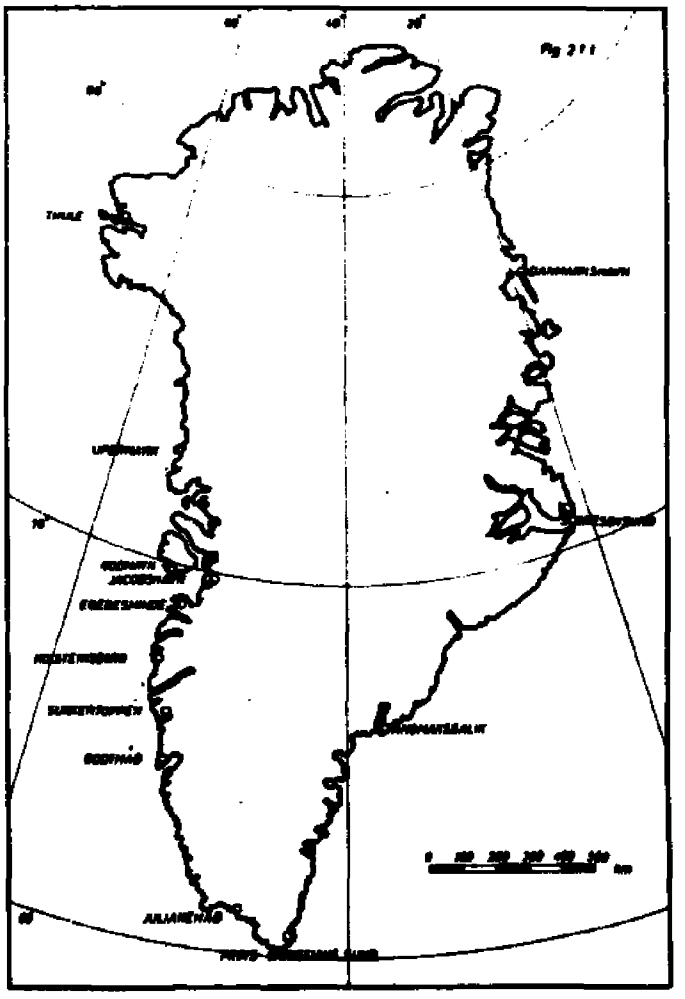

Fig. 1. Greenland

1.4.

The environmental studies in Greenland were carried out along with corresponding investigations in Denmark (cf. Risø Report No. 245[2]) and in the Faroes (cf. Risø Report No. 246[3]).

1.5.

The present report will not repeat information concerning sample collection and analysis already given in ref. 1.

2. RESULTS AND DISCUSSION

2.1. Sr-90 in Precipitation

Table 2.1.1 shows the results of the measurements.

The total fall-out levels in 1970 at Upernavik and Godthåb were respectively 1.9 and 1.5 times the 1969 figures. The specific activity at these stations was on the average a factor of two higher in 1970 than in 1969. In Denmark[2] and the Faroes[3] the fall-out levels also increased from 1969 to 1970 (cf. also fig. 2.1.2).

Table 2.1.1

Sr-90 in precipitation collected in Greenland in 1970

Location	Unit	Jan.-Mar.	Apr.-June	July-Sept.	Oct.-Dec.	1970
Upernavik	pCi/l	0.44	1.11	2.08	1.74	$\bar{x}$ 1.96
Σ 171 mm	mCi/km^2	0.035	0.030	0.17	0.10	Σ 0.34
Godhavn	pCi/l	0.94	2.54	1.44		$\bar{x}$ ~ 1.2
Σ 487 mm	mCi/km^2	0.060	0.084	0.26		Σ ~ 0.6
Godthåb	pCi/l	0.60	1.75	2.82	0.66	$\bar{x}$ 1.53
Σ 609 mm	mCi/km^2	0.12	0.19	0.56	0.063	Σ 0.93
Prins Chr. Sund	pCi/l	0.54	0.61	0.95		$\bar{x}$ ~ 0.7
Σ 2325 mm	mCi/km^2	0.23	0.26	0.44		Σ ~ 1.6
Kap Tobin	pCi/l		1.58	1.44	1.00	$\bar{x}$ ~ 1.4
Σ 628 mm	mCi/km^2		0.29	0.22	0.07	Σ ~ 0.9

2.2. Sr-90 in Sea Water

Six sea-water samples from the Greenland coastal waters were obtained in 1970. Table 2.2.1 shows the results.

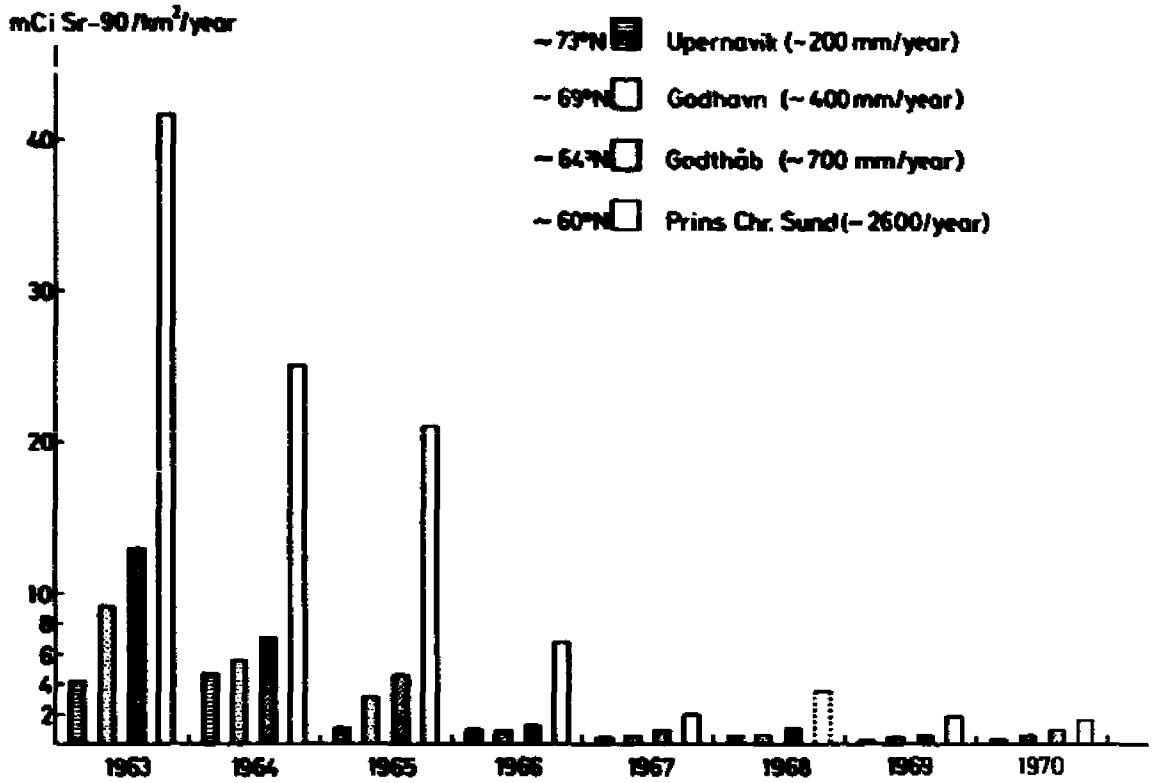

Fig. 2. I. 1. Annual Sr-90 fallout at four Greenland locations in 1963-70

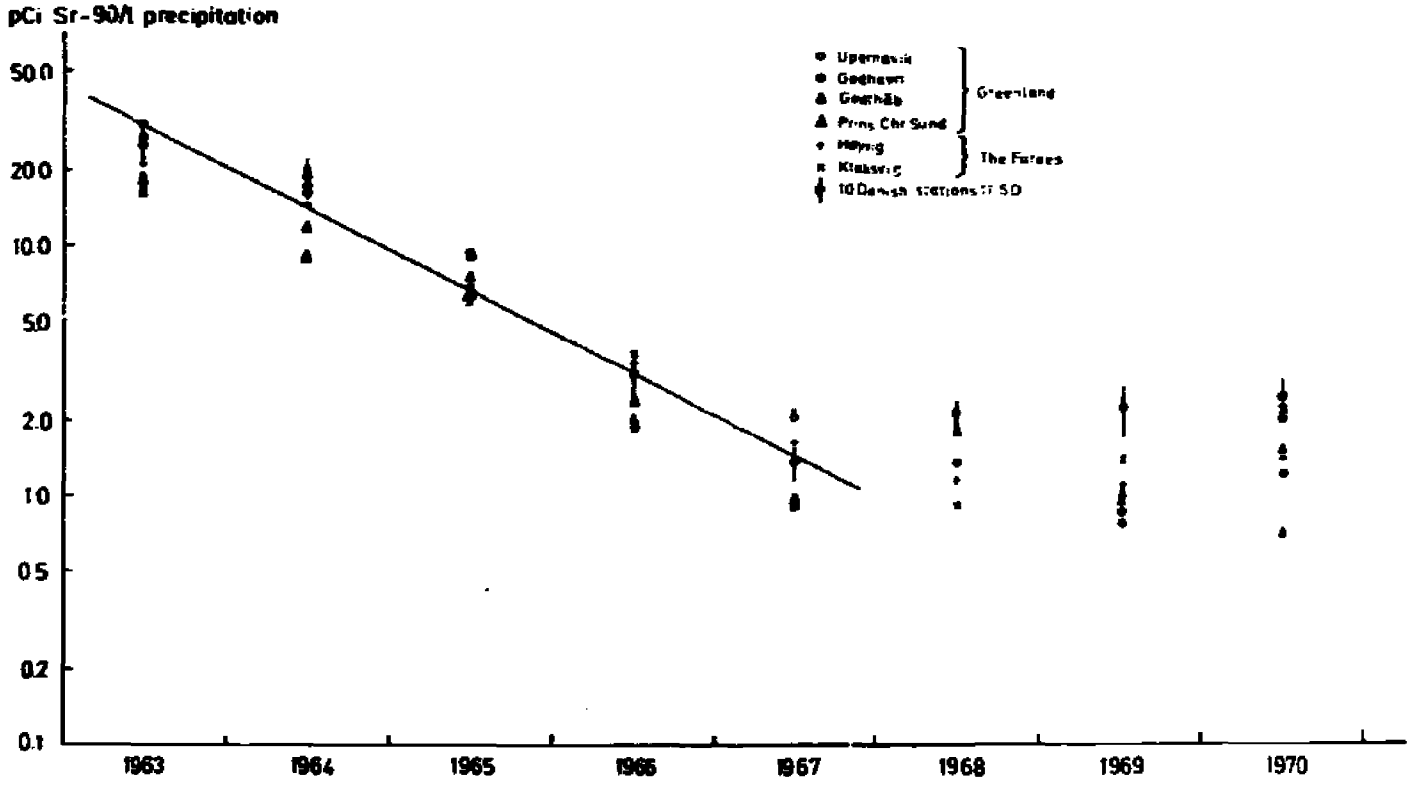

Fig. 2. 1. 2. Annual specific mean activity of Sr-90 in precipitation collected in Denmark, the Faroes and Greenland in 1963-70. The regression curve $y = 44.7\ e^{-0.76t}$ was calculated from the ten Danish stations in 1963-67

Table 2.2.1

Sr-90 in surface sea water collected around Greenland
in July-August 1970

Location	Position		pCi Sr-90/l	Salinity in o/oo
	N	W		
Danmarkshavn	77°	18°	0.37	6.7
Godhavn	69°	54°	0.11	31.1
Prins Chr. Sund	60°	44°	0.21	28.9
Thule	77°	70°	0.12	29.1
Angmagsalik	65°	38°	0.22	28.4
Godthåb	64°	52°	0.19	27.6

Table 2.2.2

Sr-90 in Greenland sea water
collected from Godthåb to Thule in August 1970

Location	Position		Depth in m	pCi Sr-90/l	Salinity in o/oo
	N	W			
Godthåb	64°04'	52°04'	0	0.16	29.4
-"-	-	-	400	0.12	33.2
Hare Isl.	70°36'	55°01'	0	0.14	32.5
-"-	-	-	370	0.06	34.9
Eiderduck Isl.	77°	58°05'	0	0.10	32.5
-"-	-	-	500	0.04	34.5
Bylot Sound	76°38'	69°30'	0	0.10	31.4
-"-	-	-	112	0.08	33.6
-"-	76°31'	69°17'	0	0.09	32.9
-"-	-	-	185	0.09	33.4

The mean level was nearly the same as in 1966-69 (approx. 0.2 pCi Sr-90/l).

In the period 1967-70 Danmarkshavn has shown significantly higher levels (0.31 pCi Sr-90/l, 1 S.E.: 0.02) than Prins Chr. Sund (0.22 pCi Sr-90/l, 1 S.E.: 0.01) and Godhavn (0.14 pCi Sr-90/l, 1 S.E.: 0.02). This indicates a higher Sr-90 concentration in coastal waters from the (north)east side of Greenland than from the (north) west side.

In connection with an expedition to Thule in the summer of 1970 a number of sea water samples were collected along the Greenland west coast from Godthåb to Thule. Table 2.2.2 shows the results of the Sr-90 determination.

When compared with table 2.2.1 it is evident that the levels in table 2.2.2 are lower. This is due to the fact that the Thule samples were collected from open water and not from the coast (cf. the higher salinities in table 2.2.2). Table 2.2.2 also shows that the deep stations had lower Sr-90 levels (and higher salinities) than the surface stations.

Table 2.3.1

Sr-90 and Cs-137 in reindeer and musk ox collected in Greenland in 1970

Month	Location	Species	Sample type	pCi Sr-90/kg	pCi Sr-90/g Ca	nCi Cs-137/kg	pCi Cs-137/g K
Mar.	Egedesminde	Reindeer	Meat	24	395	6.98	2650
Mar.	Egedesminde	Reindeer	Bone	-	340		-
June	Holsteinsborg	Reindeer	Meat	30	93	9.33	3200
June	Holsteinsborg	Reindeer	Bone	-	350	-	-
July	Danmarkshavn	Musk ox	Meat	7.3	74	0.19	42
July	Danmarkshavn	Musk ox	Bone	-	63	-	-
Dec.	Holsteinsborg	Wild reindeer	Meat	28	215	1.80	475
Dec.	Holsteinsborg	Wild reindeer	Bone	-	250	-	-

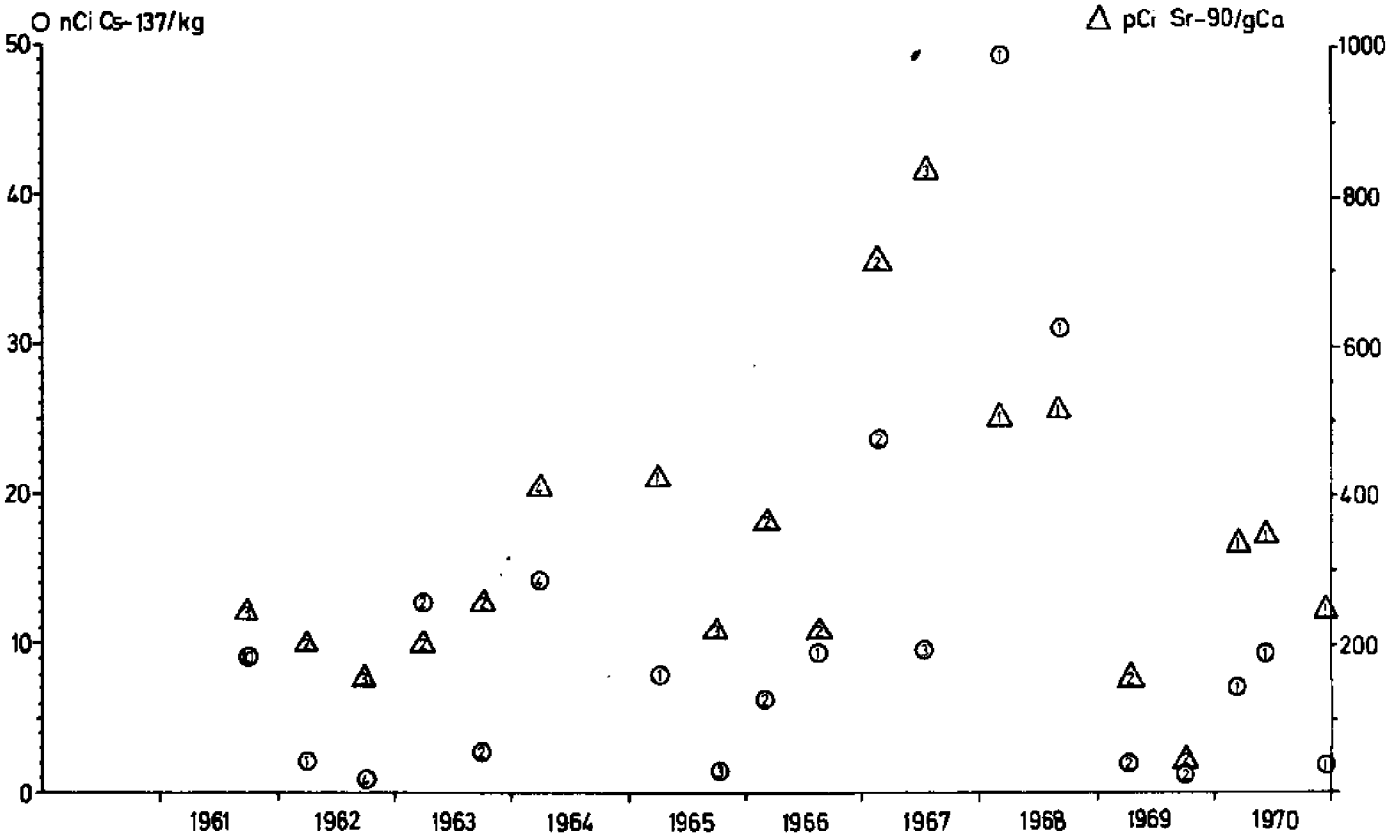

Fig. 2.3. Geometric mean levels of Sr-90 in reindeer bone and Cs-137 in reindeer meat in S.W. Greenland in 1961-70 (the figures are the numbers of samples included in the means)

2.3. Sr-90 and Cs-137 in Terrestrial Animals

Samples of reindeer were collected in the spring and the autumn from Egedesminde and Holsteinsborg on the west coast of Greenland. Table 2.3.1 shows the results.

The means of the samples were 27 pCi Sr-90/kg meat and 6 nCi Cs-137/kg, i.e. an increase from 1969, cf. fig. 2.3 which shows the geometric means of Sr-90 in bone and Cs-137 in meat of reindeer from Greenland collected in the period 1961-70 (cf. the comments given in Risø Report No. 132[1]).

A musk ox sample was obtained from Danmarkshavn, the Cs-137 level was similar to those found in animals from the previous years[1].

2.4. Sr-90 and Cs-137 in Sea Animals

The mean levels in fish and shrimps (flesh) were 1.8 pCi Sr-90/kg and 7 pCi Cs-137/kg (cf. table 2.4.1).

Table 2.4.1

Sr-90 and Cs-137 in sea animals collected around Greenland in '970

Month	Location	Species	Sample type	pCi Sr-90/kg	pCi Sr-90/g Ca	pCi Cs-137/kg	pCi Cs-137/g K
June	Egedesminde	Angmasetter	Meat	1.43	0.42	1.43	4.35
Aug.	Jacobshavn	Shrimps	Total animal	11.25	0.94	0	0
Aug.	Jacobshavn	Shrimps	Meat	1.42	2.05	1.04	0.32
Aug.	Holsteinsborg	Salmon	Meat	3.62	11.98	19.38	4.02
July	Christianshåb	Shrimps	Total animal	3.74	0.31	6.00	2.34
July	Christianshåb	Shrimps	Meat	1.04	0.73	16.65	5.02
July	Christianshåb	Shrimps	Shell	5.20	0.27	-	-
Dec.	Holsteinsborg	Whale	Meat	0.98	8.62	29.79	8.54
Aug.	Holsteinsborg	Salmon	Bone	-	8.08	-	-

2.5. Sr-90 and Cs-137 in Vegetation

Seaweed, grass, lichen, and moss were collected from eight stations along the Greenland coast during the summer. Table 2.5 shows the results.

Fig. 2.5.1 shows the annual geometric mean values of Sr-90 and Cs-137 in grass samples collected at the west coast between Egedesminde (~69°N) and Julianehåb (~61°N) since 1962.

Fig 2.5.2 shows the levels of Sr-90 and Cs-137 since 1962 in lichen collected along the Greenland coast. No significant reduction of the activity levels was observed in the period.

Table 2.5

Sr-90 and Cs-137 in vegetation samples collected in Greenland in 1970

Month	Location	Species	pCi Sr-90/kg	pCi Sr-90/g Ca	pCi Cs-137/kg	pCi Cs-137/g K
Autumn	Upernavik	Seaweed	18	1.90	43	1.1
Autumn	Pr. Chr. Sund	Seaweed	83	4.54	160	6.0
Autumn	Danmarkshavn	Seaweed	83	6.27	210	12.9
Autumn	Upernavik	Lichen	-	-	15600	1800
Autumn	Christianshåb	Lichen	5900	900	7300	2000
Autumn	Egedesminde	Lichen	10000	4000	18300	6100
Autumn	Godthåb	Lichen	6900	5200	13300	1400
Autumn	Holsteinsborg	Lichen	1900	3500	14900	2800
Autumn	Danmarkshavn	Lichen	8600	690	10700	1320
Autumn	Pr. Chr. Sund	Moss	3100	650	8900	240
Autumn	Godthåb	Grass	2600	1650	1250	95

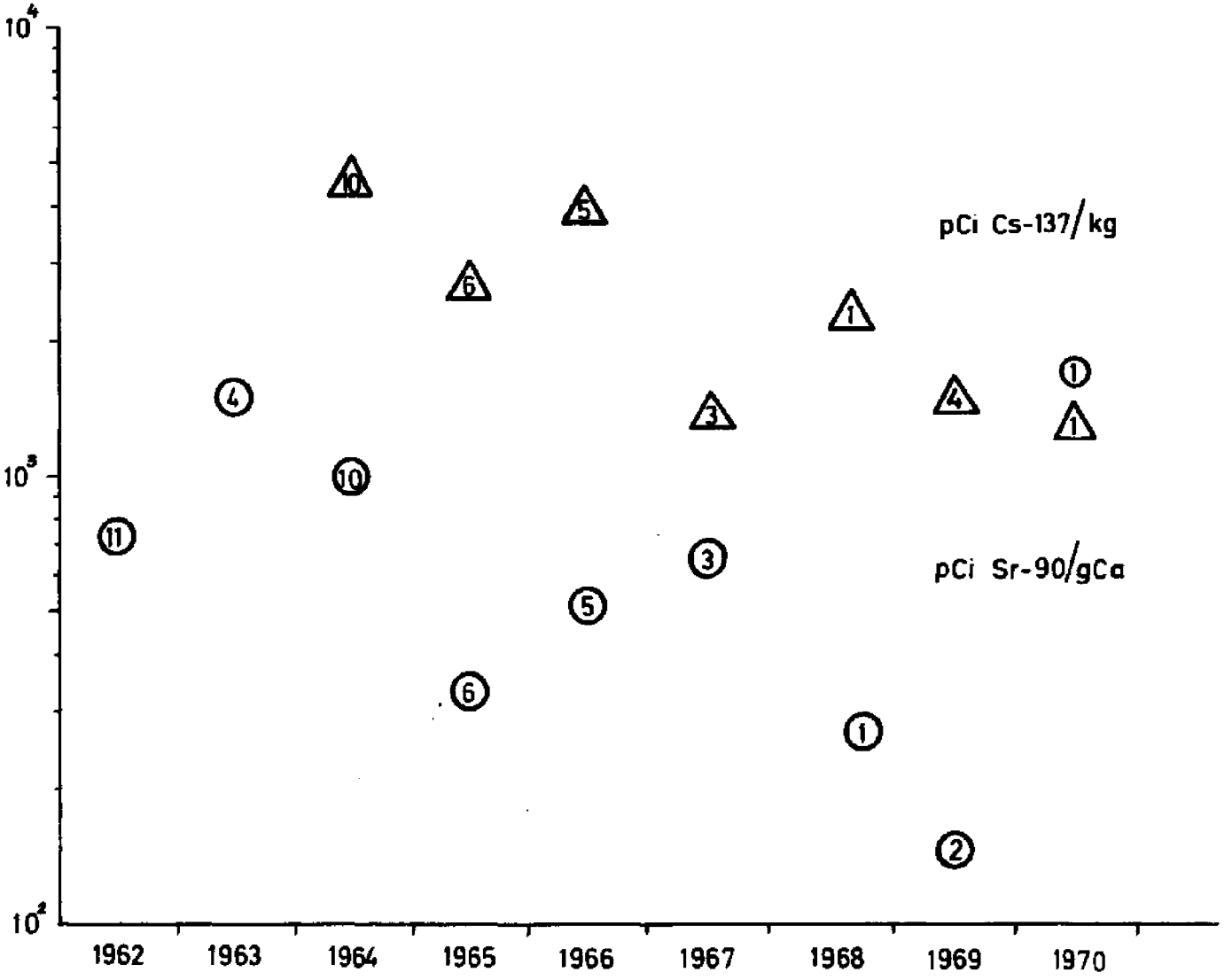

Fig. 2.5.1. Geometric mean levels of Sr-90 and Cs-137 in grass and hay collected at the west coast of Greenland in 1962-70. The numbers of samples included in the means are indicated

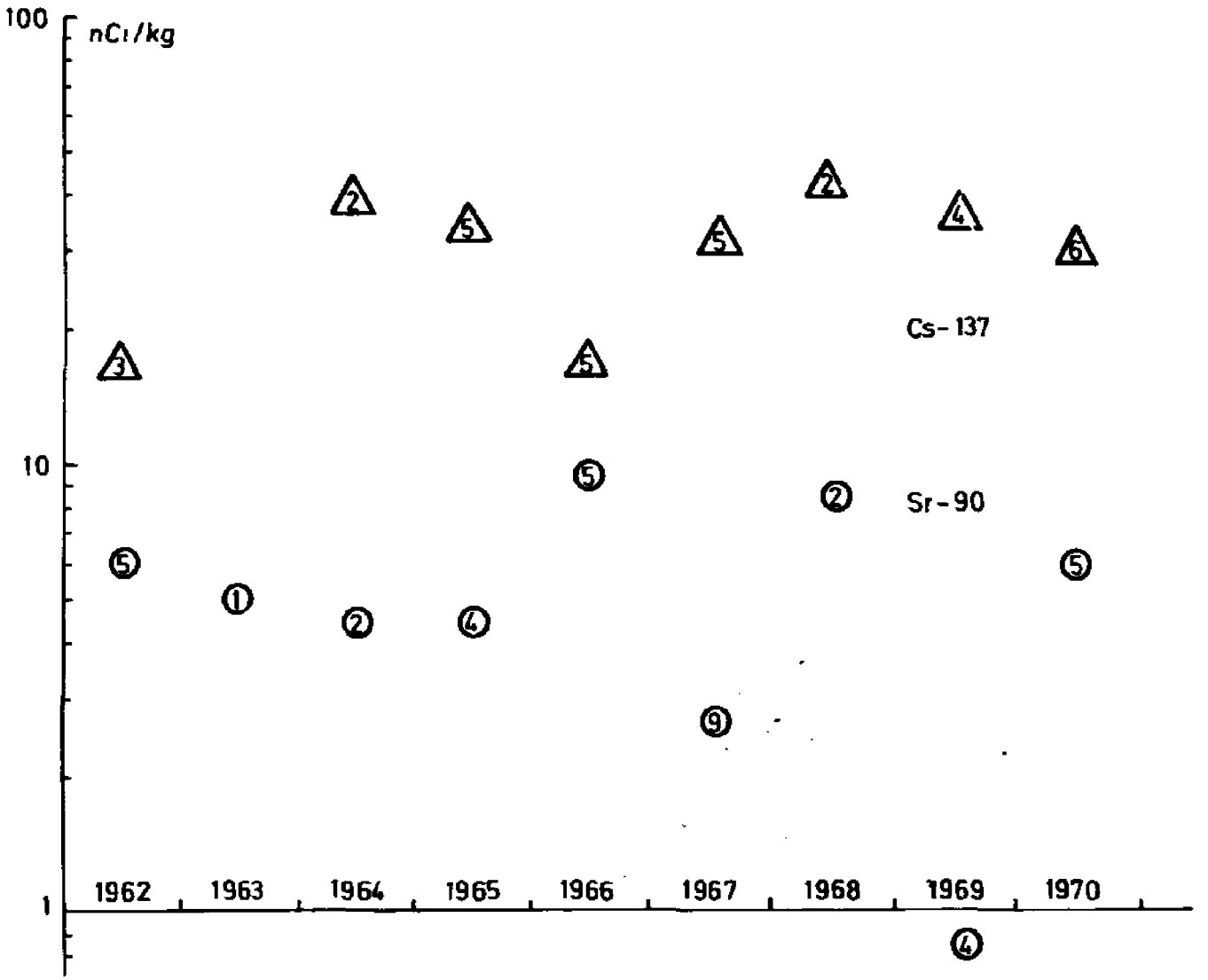

Fig. 2. 5. 2. Geometric mean levels of Sr-90 and Cs-137 in lichen samples collected in Greenland in 1962-70. The numbers of samples included in the means are indicated

2.6. Radiostrontium in Drinking Water

Quaterly samples of drinking water were as previously collected from a number of locations in Greenland. Table 2.6 shows the results from 1970 and fig. 2.6 the results from four of the locations for the period 1962-1970.

As in the previous years, we found it most expedient to choose the geometric mean of all figures, i.e. 0.31 pCi Sr-90/l, as representative of the mean level of Sr-90 in Greenland drinking water in 1970.

Table 2.6

Sr-90 in drinking water collected in Greenland in 1970
(pCi Sr-90/l)

Location	Jan.-Mar.	Apr.-June	July-Sept.	Oct.-Dec.
Danmarkshavn	0.32	0.81	0.33	0.90
Prins Chr. Sund	1.12	0.93	0.55	
Godthåb	0.82	0.65±0.15	0.94	
Godhavn	0.018	0.11	0.059	
Upernavik		0.027		

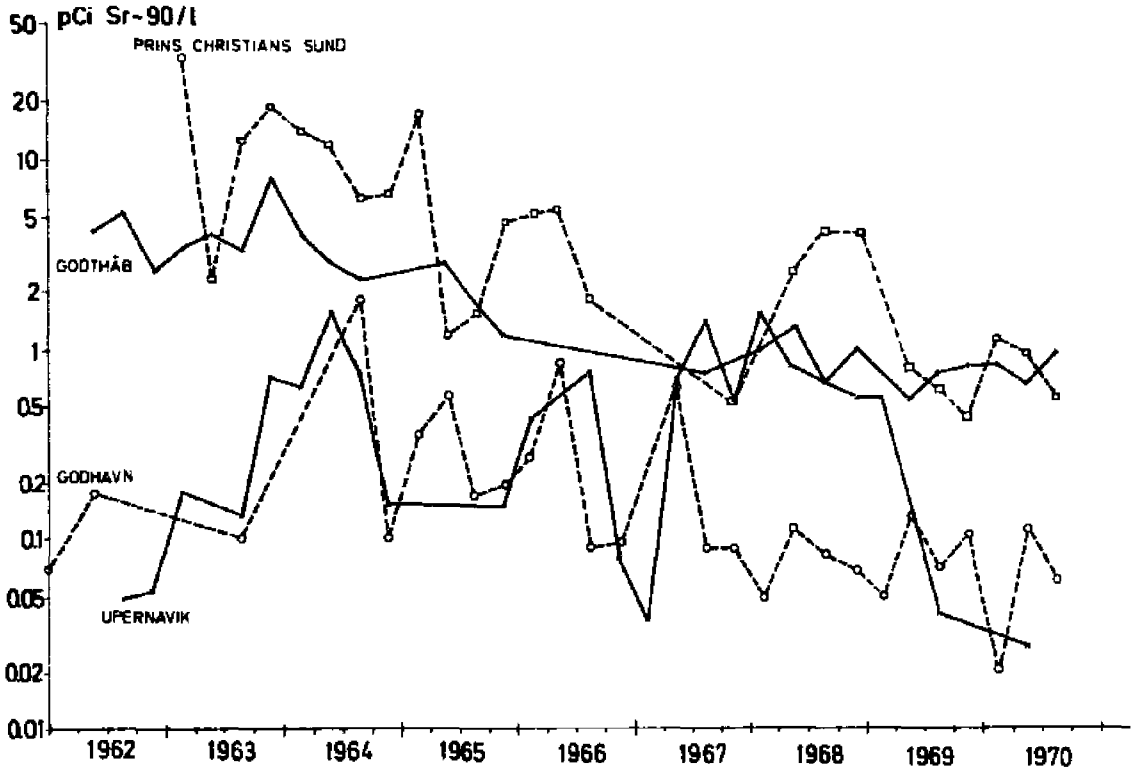

Fig. 2.6. Sr-90 in Greenland drinking water, 1962-70

3. ESTIMATE OF THE MEAN CONTENTS OF Sr-90 AND Cs-137 IN THE HUMAN DIET IN GREENLAND IN 1970

3.1. The Annual Quantities

The estimate of the daily per capita intake of the different foods in Greenland is still based on the figures given in 1962 by Professor E. Hoff-Jørgensen, Ph.D. in Risø Report No. 65[1].

3.2. Milk Products

All milk consumed in Greenland was imported as milk powder from Denmark. The mean radioactivity content in milk prepared from Danish dried milk produced in 1970 was 8.8 pCi Sr-90/kg and 14 pCi Cs-137/kg[2].

The cheese was also imported from Denmark and contained 62 pCi Sr-90/kg and 10 pCi Cs-137/kg.

3.3. Grain Products

All grain was imported from Denmark. It is assumed that only grain from the harvest of 1969 was consumed in Greenland during 1970. The daily per capita consumption was: rye flour (100 % extraction): 80 g, wheat flour (75% extraction): 110 g, rye flour (70% extraction): 20 g, biscuits (rye, 100% extraction): 27 g, and grits: 25 g. The content of Sr-90 in these five products was 36, 6, 7, 27, and 16 pCi/kg respectively. Hence the mean content of Sr-90 in grain products was 18 pCi/kg. The content of Cs-137 in the five products was 59, 19, 30, 44, and 23 pCi/kg. Hence the mean content of Cs-137 in grain products was 35 pCi/kg.

The activity levels in rye flour (100% extraction), wheat flour (75% extraction) and grits were all taken from tables 5.9.1 and 5.9.2 in Risö Report No. 245[2]. The Sr-90 level in rye flour (70% extraction) was calculated by analogy with the level in wheat flour (75% extraction), i.e. as one-fifth of the whole-grain activity. The Cs-137 content in rye flour (70% extraction) was calculated as one half of the wholegrain level in rye, i.e. the ratio between Cs-137 in whole wheat grain and in wheat flour (75% extraction)[2]. The Sr-90 and Cs-137 contents in biscuits were calculated by dividing the levels of the rye flour (100% extraction) by 1.35, since 1 kg flour yields 1.35 kg bread[2].

3.4. Potatoes, Other Vegetables and Fruit

The Danish mean levels for 1970 were used[2] as the local production is insignificant as compared with the imports from Denmark.

The Danish mean levels were: in potatoes 3.3 pCi Sr-90/kg and 12.4 pCi Cs-137/kg, in other vegetables 10 pCi Sr-90/kg and 4.6 pCi Cs-137/kg, and in fruit 3.1 pCi Sr-90/kg and 9.4 pCi Cs-137/kg.

3.5. Meat

Nearly all meat consumed in Greenland is assumed to be of local origin. Approx. 10% comes from sheep, 5% from reindeer, 60% from seals, 5% from whales, and 20% from sea birds and eggs.

The activity in lamb and reindeer was estimated from reindeer (cf. 2.3). Reindeer contained 27 pCi Sr-90/kg and 6 nCi Cs-137/kg. Seals and whales were estimated from table 2.4.1 to have contained 1 pCi Sr-90/kg and 30 pCi Cs-137/kg, and sea birds and eggs were estimated to have contained the same as in 1969 i.e. 0.14 pCi Sr-90/kg and 90 pCi Cs-137/kg. Hence the mean levels in Greenland meat from 1970 were 4.7 pCi Sr-90/kg and 938 pCi Cs-137/kg.

3.6. Fish

All fish consumed was of local origin, and the mean levels from table 2.4.2 were used, i.e. 1.8 pCi Sr-90/kg and 7 pCi Cs-137/kg.

3.7. Coffee and Tea

The Danish figures for 1970[2)] were used for coffee and tea, i.e. 27 pCi Sr-90/kg and 168 pCi Cs-137/kg.

3.8. Drinking Water

The geometric mean calculated in 2.6 was used as the mean level of

Table 3.1

Estimate of the mean content of Sr-90 in the human diet in Greenland in 1970

Type of food	Annual quantity in kg	pCi Sr-90 per kg	Total pCi Sr-90	Percentage of total Sr-90 in food
Milk and cream	78	8.8	686	19.2
Cheese	2.5	62	155	4.3
Grain products	95.6	18	1721	48.1
Potatoes	32.8	3.3	108	3.0
Vegetables	5.5	10	55	1.6
Fruit	13.5	3.1	42	1.2
Meat and eggs	45.6	4.7	214	6.0
Fish	127.6	1.8	230	6.4
Coffee and tea	7.3	27	197	5.5
Drinking water	548	0.31	169	4.7
Total			3577	

The mean annual intake of calcium is estimated to be 560 g (approx. 200 - 250 g creta praeparata). Hence the Sr-90/g Ca ratio in Greenland total diet in 1970 was 6.4 pCi Sr-90/g Ca and the daily intake 9.8 pCi Sr-90

Table 3.2

Estimate of the mean content of Cs-137 in the human diet in Greenland in 1970

Type of food	Annual quantity in kg	pCi Cs-137 per kg	Total pCi Cs-137	Percentage of total Cs-137 in food
Milk and cream	78	14	1092	2.2
Cheese	2.5	10	25	0.1
Grain products	95.6	35	3346	6.7
Potatoes	32.8	12.4	407	0.8
Vegetables	5.5	4.6	25	0.1
Fruit	13.5	9.4	127	0.2
Meat and eggs	45.6	938	42773	85.6
Fish	127.6	7	893	1.8
Coffee and tea	7.3	168	1226	2.4
Drinking water	548	0.1	55	0.1
Total			49969	

The mean annual intake of potassium is estimated to be approx. 1200 g. Hence the Cs-137/g K ratio becomes 42 pCi Cs-137/g K. The daily intake in 1970 from food was 137 pCi Cs-137.

Sr-90 in drinking water, i.e. 0.31 pCi Sr-90/l. The Cs-137 content was as previously[1] estimated at 1/4 of the Sr-90 content, i.e. approx. 0.1 pCi Cs-137/l.

Tables 3.1 and 3.2 show the estimates of Sr-90 and Cs-137 respectively.

3.9. Discussion

As previously, the most important Sr-90 source in the diet in Greenland was grain products, which contributed 48.1% of the total Sr-90 content of the diet. Milk and fish came next in importance, contributing 19.2 and 6.4% respectively. Approx. 85% of the Sr-90 in the food consumed in Greenland in 1970 came from imported Danish food; this is in agreement with earlier years' observations.

Meat was as previously the most important Cs-137 source in the Greenland diet in 1970, contributing 86% of the total content. Approx. nine tenths of the Cs-137 in the Greenland diet in 1970 came from local products.

As compared with the 1969 figures, the Sr-90 content in the total diet in 1970 was 15% lower than the 1969 level but the Cs-137 level was higher by a factor of 2. The Cs-137 levels in the Greenland diet have been very

dependent on the levels in reindeer samples; in 1968 e.g. the reindeer meat (2 samples) contained 46.6 nCi Cs-137/kg, in 1969 the level was only 1.7 nCi/kg (4 samples), and in 1970 the mean level was 6 nCi (3 samples).

To estimate the maximum per capita intakes of Sr-90 and Cs-137 in Greenland in 1970 we will suppose, as in the previous years[1], that the only grain product consumed by a person was dark rye bread, that all his meat came from reindeer, and that his drinking water was rain water with a specific mean activity of 1.5 pCi Sr-90/l and 2.4 pCi Cs-137/l (cf. table 2.2.2). His daily intake of Sr-90 would thus be 19 pCi (12 S.U.) and his Cs-137 intake 760 pCi/day (if we use the quantities in tables 3.1 and 3.2). At the lower limit we can imagine someone who ate white bread and seal or whale meat and drank water with hardly any activity (e.g. water formed by the melting of old ice). In this case the daily intakes would be 8.4 pCi Sr-90 (5.4 S.U.) and 20 pCi Cs-137. Hence the ratios between the levels in the maximum and the minimum diets become 2 for Sr-90 and 38 for Cs-137.

The Sr-90 content of the Greenland diet was a little lower than the estimated Danish mean content[2], and half the Faroese level[3]. The Cs-137 level in the total diet in Greenland was 4 times as high as that of the Danish diet and three times lower than the Faroese diet level.

4. CONCLUSION

4.1.

The Sr-90 fall-out rates in 1970 were the following: Godhavn: approx. 0.6 mCi Sr-90/km^2; Godthåb: 0.9 mCi Sr-90/km^2; Prins Christians Sund: approx. 1.6 mCi Sr-90/km^2; Upernavik: 0.3 mCi Sr-90/km^2. The accumulated fall-out levels by the end of 1970 were estimated at approx. 29 mCi Sr-90/km^2 at Godhavn, 41 mCi Sr-90/km^2 at Godthåb, 147 mCi Sr-90/km^2 at Prins Christians Sund, and 17 mCi Sr-90/km^2 at Upernavik.

The mean content of Sr-90 in surface sea water collected along the coasts of Greenland in 1970 was 0.2 pCi Sr-90/l.

4.2.

The food consumed in Greenland in 1970 contained on the average 6.4 pCi Sr-90/g Ca, and the daily mean intake of Cs-137 was estimated at 137 pCi. The most important Sr-90 contributors in the diet were grain products, and milk products, together accounting for approx. three fourths of the

total Sr-90 content of the diet. Cs-137 came mainly from meat (reindeer and lamb), contributing 86% of the total Cs-137 content of the diet.

Among the locally produced food components, reindeer meat showed the highest levels, namely up to 30 pCi Sr-90/kg and 9.3 nCi Cs-137/kg. Sea mammals and fish contained approx. 1-2 pCi Sr-90/kg and 0.01 nCi Cs-137/kg.

The levels in the quarterly drinking-water samples varied from0.03 pCi Sr-90/l, found in water from Upernavik, to 1.1 pCi Sr-90/l, found in the drinking water collected at Prins Christians Sund. The mean content in drinking water from Greenland in 1970 was estimated at 0.28 pCiSr-90/l.

4.3.

Neither Sr-90 analyses on human bone samples nor Cs-137 determinations by whole-body counting have until now been carried out on the population of Greenland. Considering the estimated Sr-90 levels in the diet, it seems probable[4], however, that the 1970 Sr-90 levels for humans in Greenland were on the average rather similar to those found in Denmark, i.e. the mean levels in human bone i Greenland were approx. 0.9 S.U. in newborn children, 1.9 S.U. in infants, 1.5 S.U. in children and teen-agers, and 1.3 S.U. in adults (vertebrae).

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